How kinetic effects might affect ignition, and in what phase space conditions

Kinetic Physics Workshop

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I tried to put together an overview of where I think there might be effects or issues

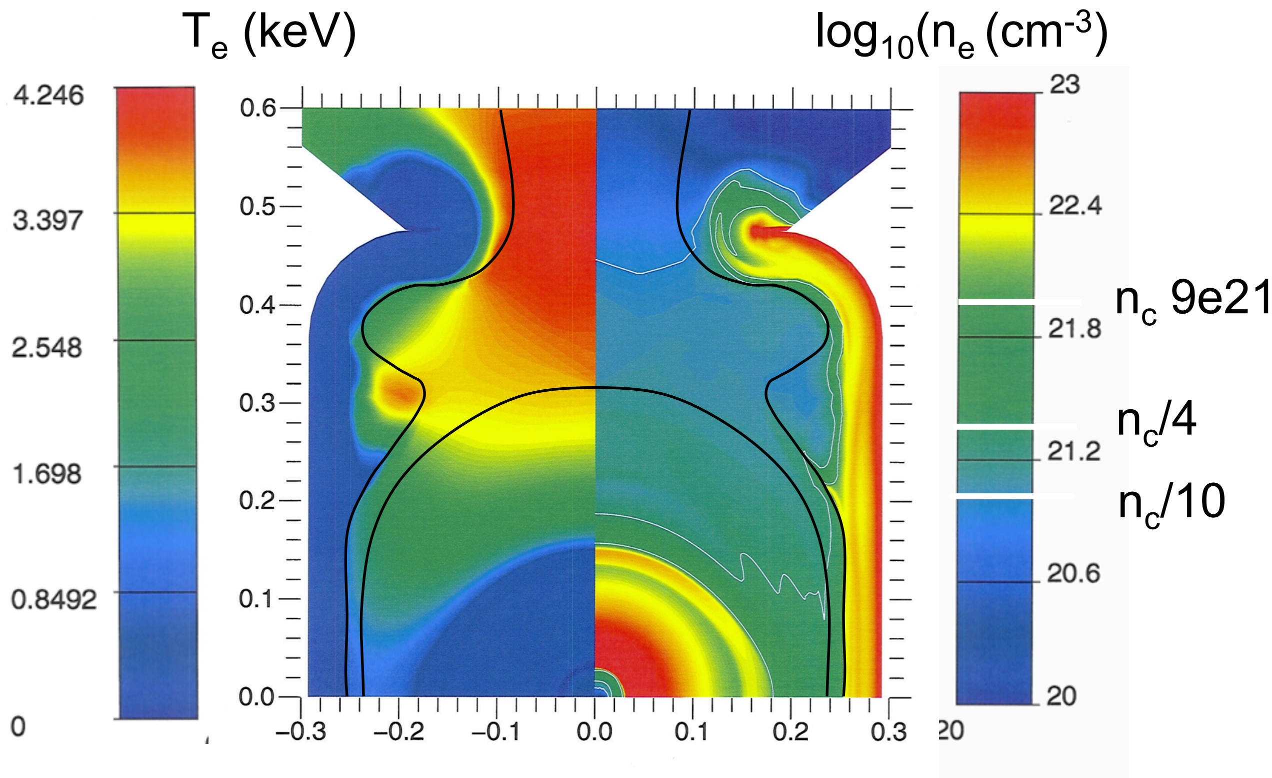
- I should be giving this talk AFTER this workshop! The ideal outcome of the workshop would be the science needed to do so.

- My outline today is simple:
  - Summary of our microphysics effort
  - Walk-through of my own take on where the issues are

We are in the process of reviewing and prioritizing microphysics issues pertinent to ICF modeling

- Goal is to have a summary of the microphysics topics, with our best effort to compare their impact & uncertainty
- Product will be working documents (spreadsheet and whitepaper), and a paper to submit to Phys Plasmas.
- This can inform decision-making and resource prioritization for experiments on NIF/Omega/LCLS etc, and theory work
- Kinetic effects are almost ubiquitous as possible issues in many areas

I will use this hohlraum drawing to walk through the issues



Hydra simulation of gas-filled hohlraum from Annie Kritcher, just at end of laser pulse

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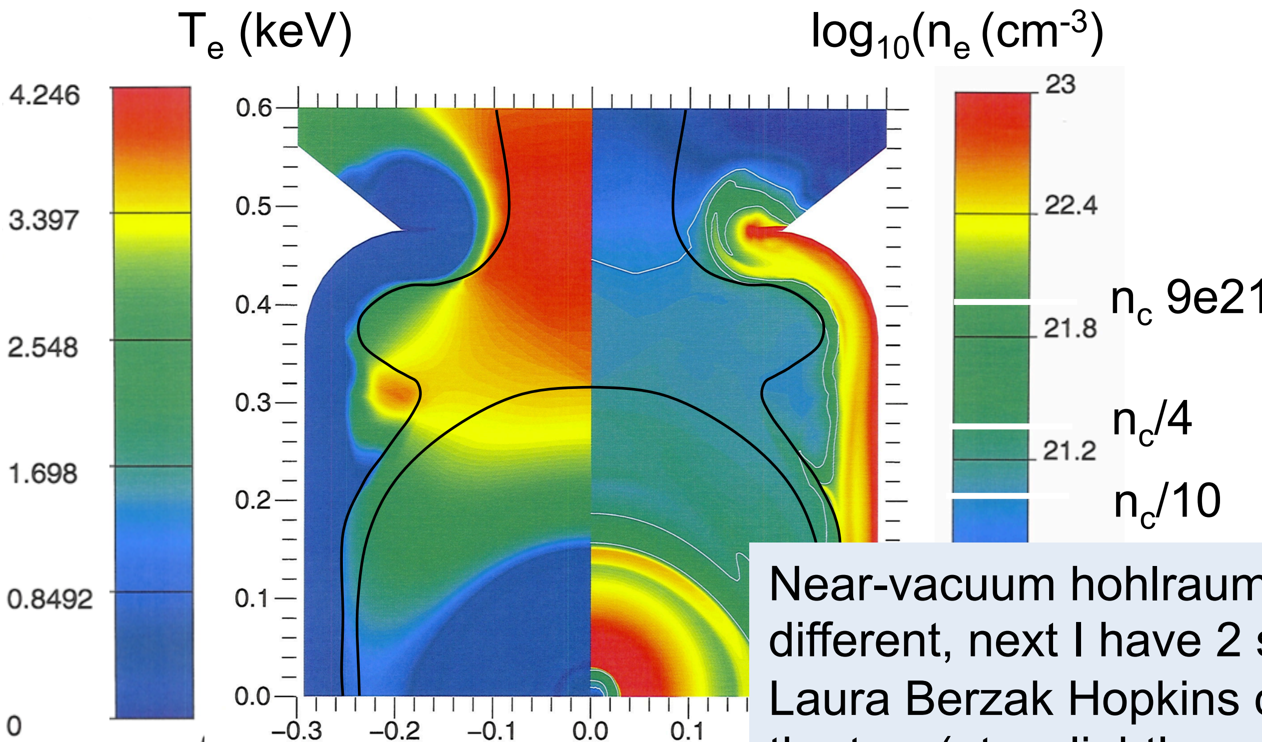
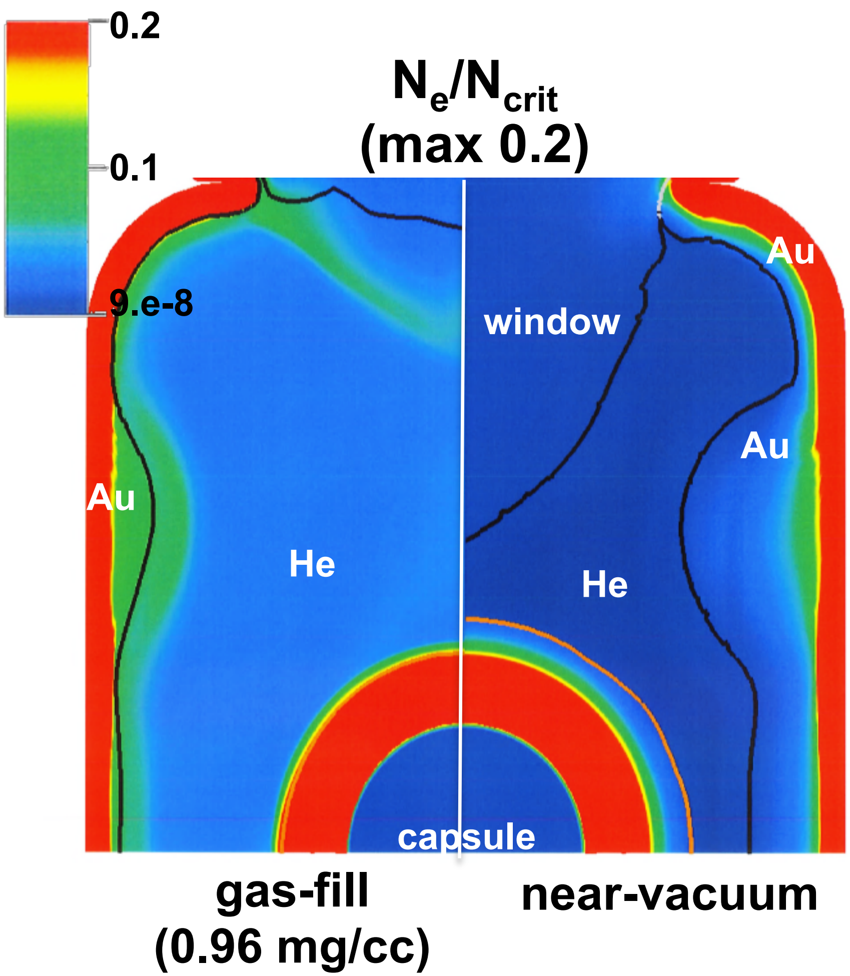
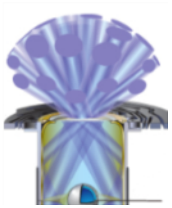


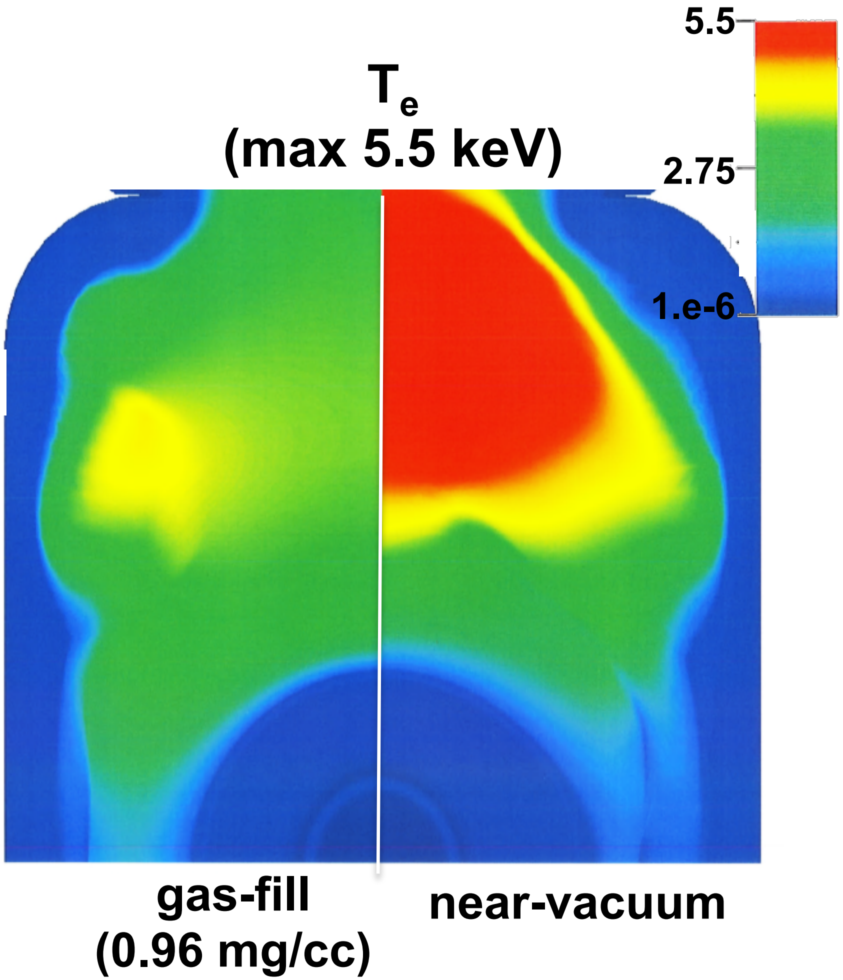
Near-vacuum hohlraums are different, next I have 2 slides from Laura Berzak Hopkins contrasting the two (at a slightly earlier time)

Hydra simulation of gas-filled hohlraum from Annie Kritcher, just at end of laser pulse

In the NVH, window and wall materials expand quickly but remain low density and high temperature





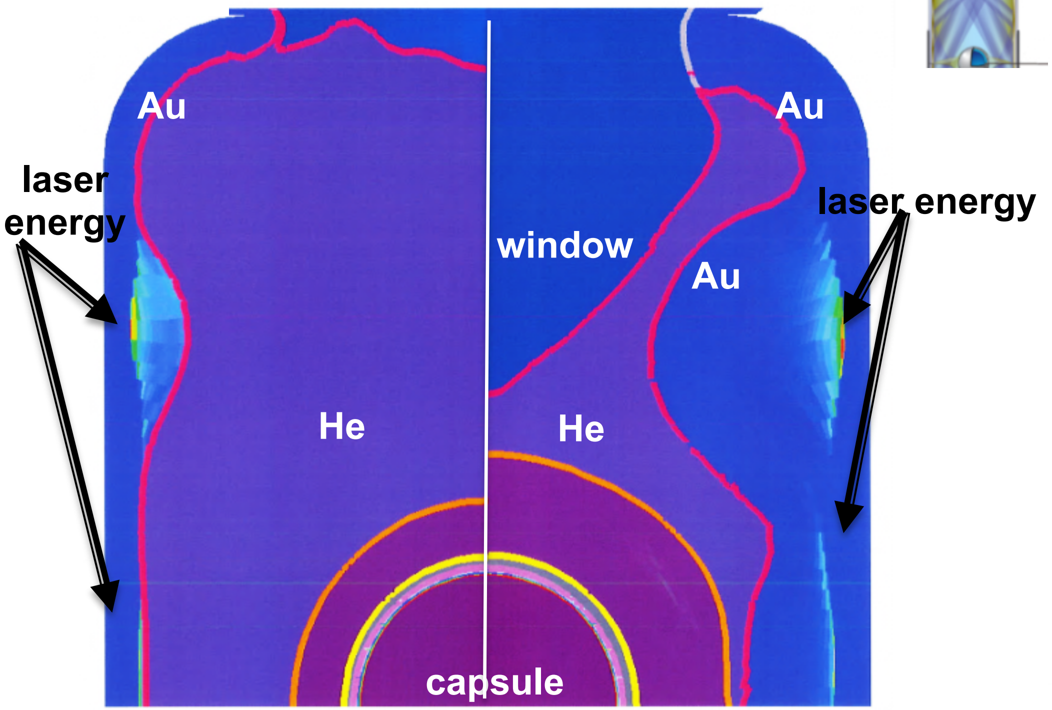


Materials remain transparent to the laser through foot and rise of pulse

Slide from Laura

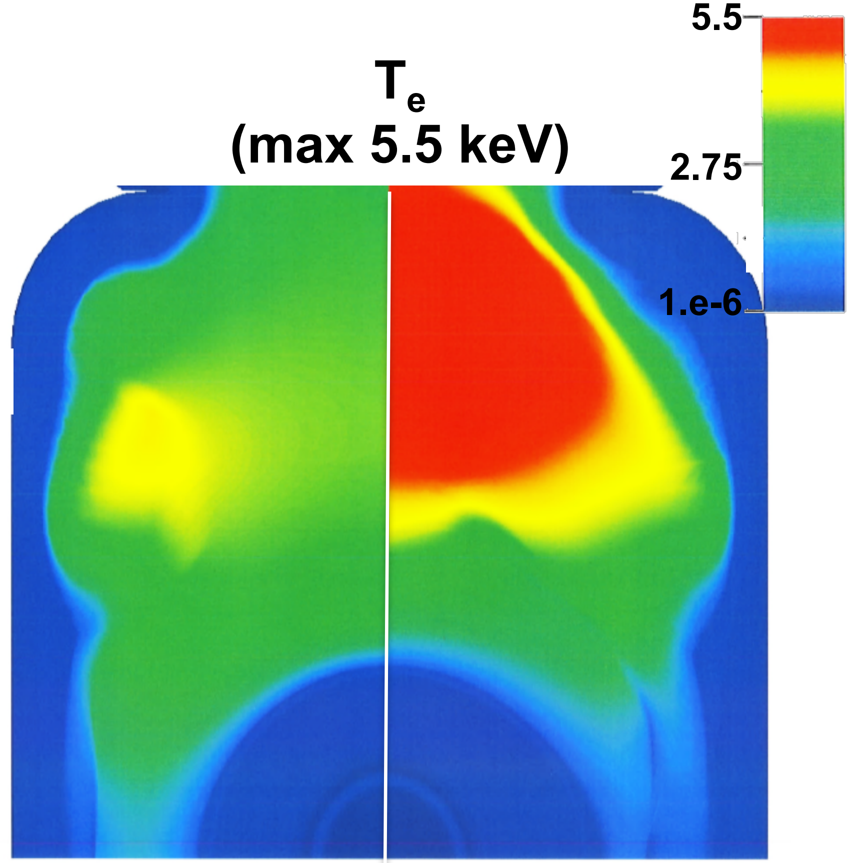
In the NVH, window and wall materials expand quickly but remain low density and high temperature

laser deposition with material boundaries



gas-fill (0.96 mg/cc)   near-vacuum

T_e (max 5.5 keV)



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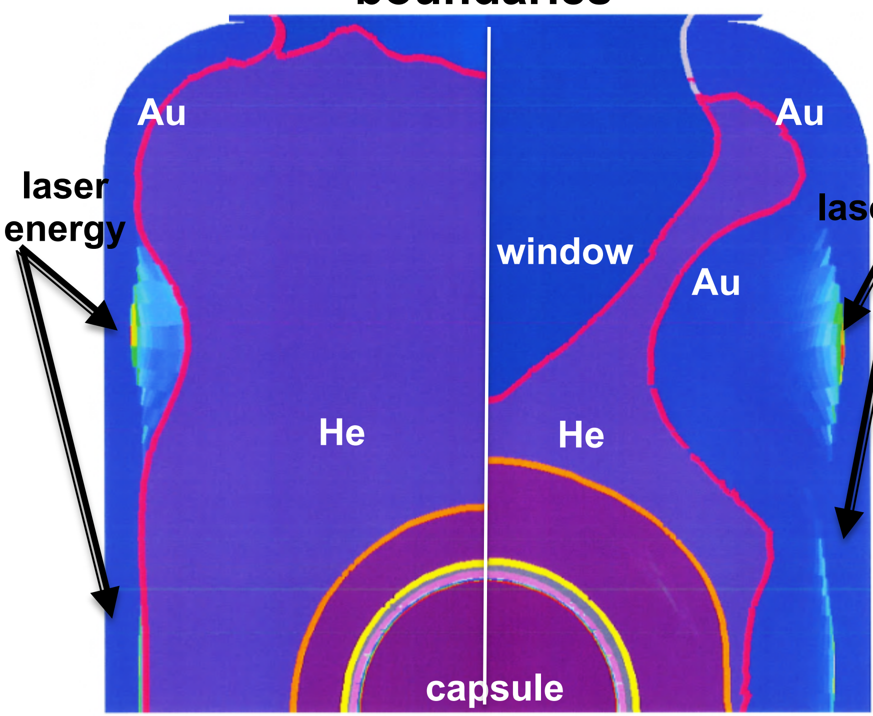
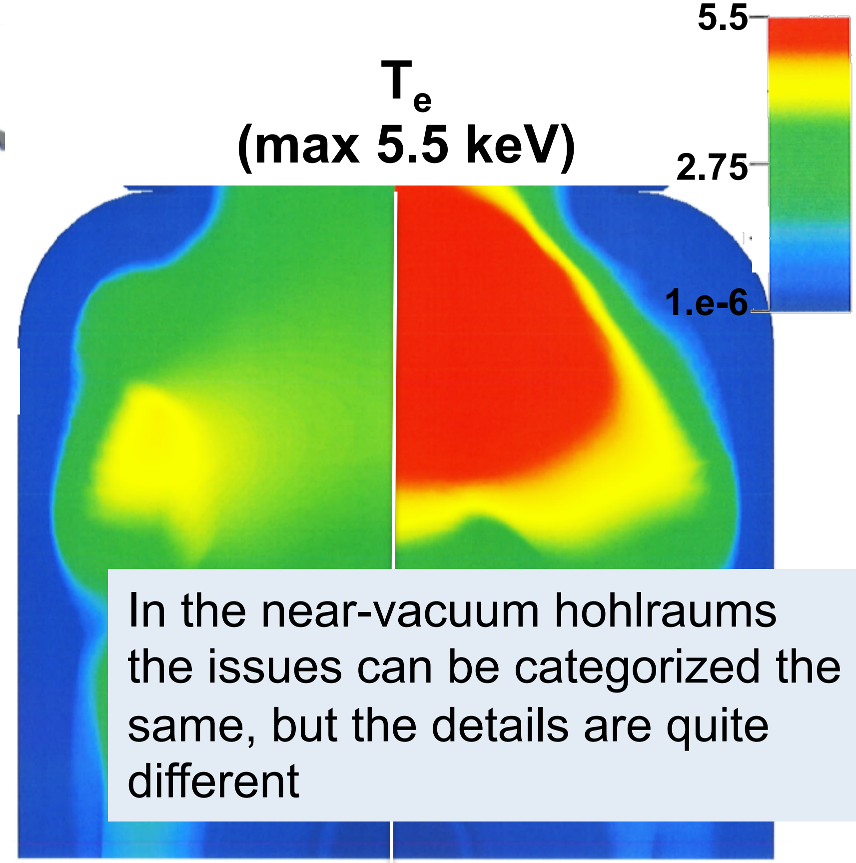


gas-fill (0.96 mg/cc) **near-vacuum**

T_e (max 5.5 keV)

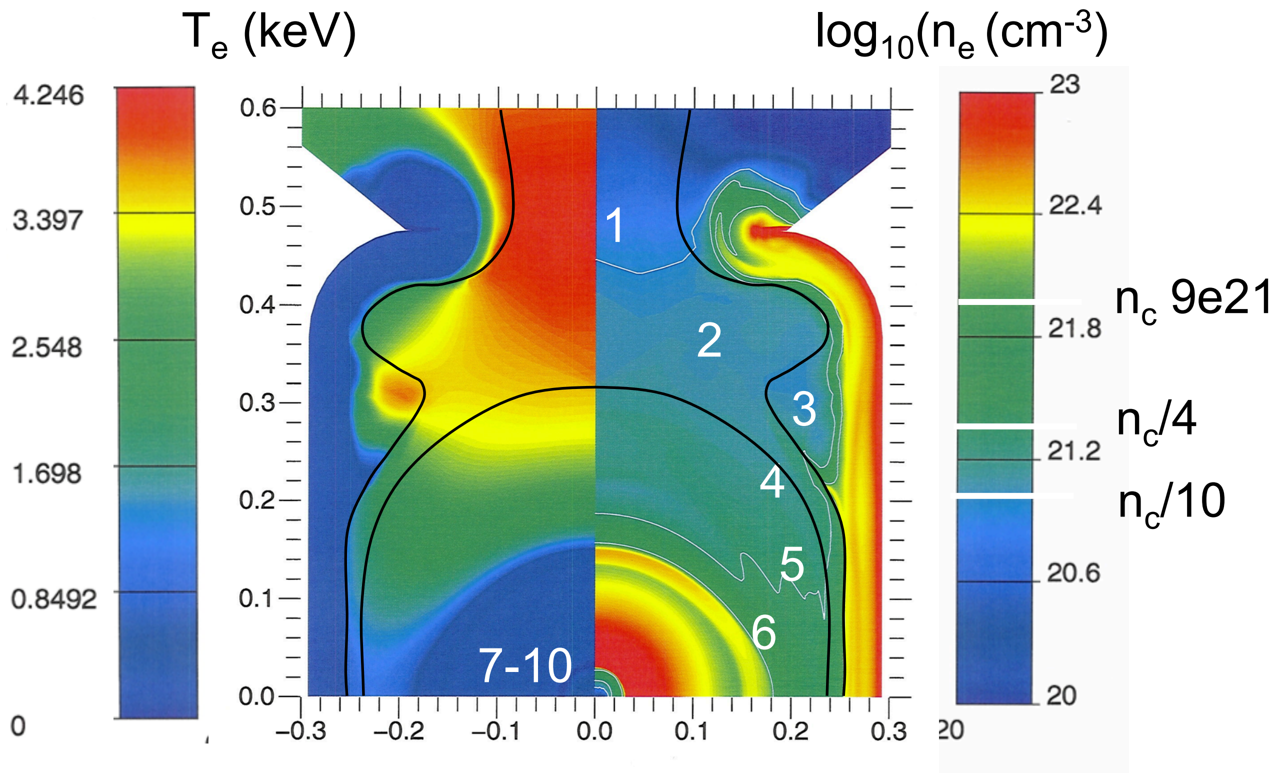


gas-fill (0.96 mg/cc) **near-vacuum**

In the near-vacuum hohlraums the issues can be categorized the same, but the details are quite different

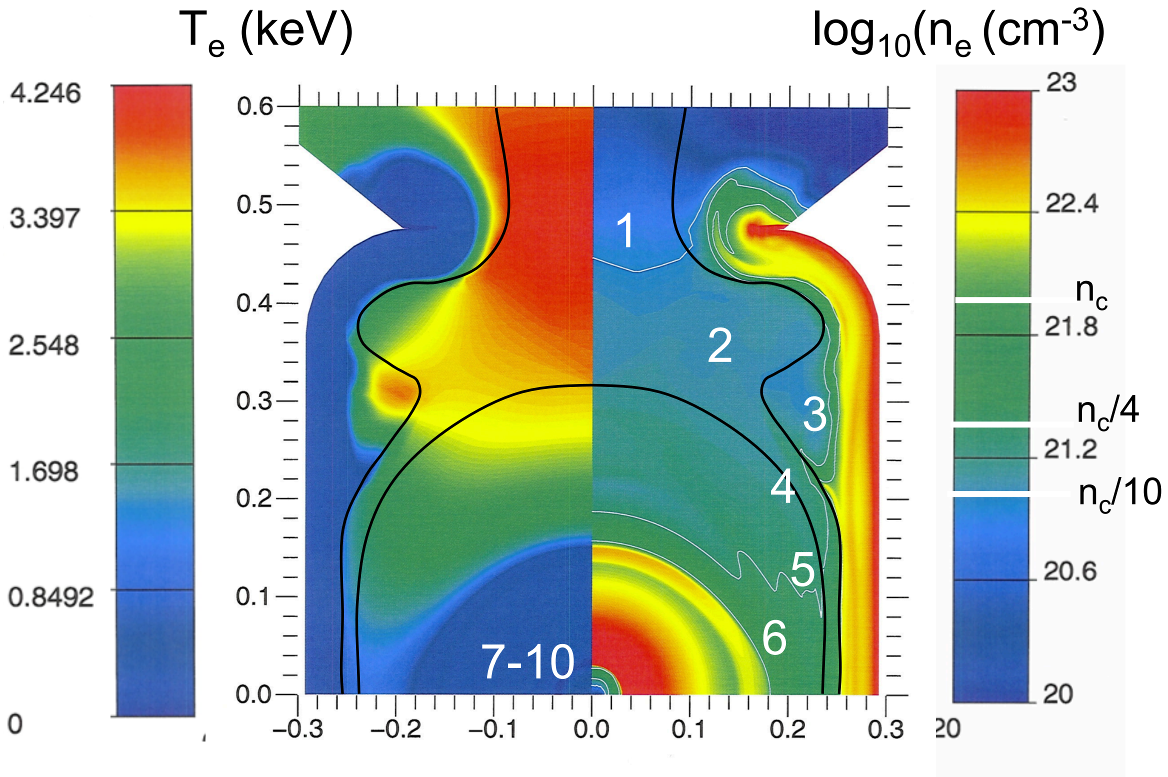
Materials remain transparent to the laser through foot and rise of pulse

I’m going to flag 10 places where kinetic effects could matter



#7-10 down in the implosion

1. Cross-beam energy transfer in the LEH

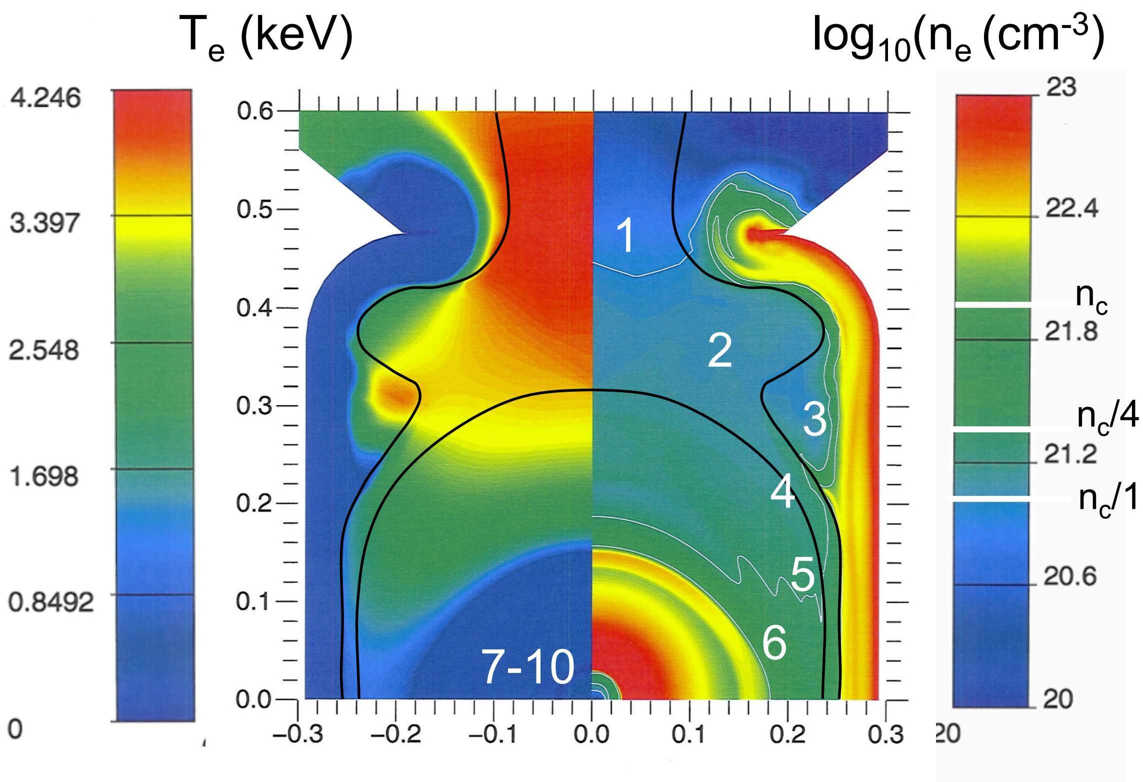


NVH:
Material: Window plastic
Density: $n_c/50$?
Temperature: 5-6 keV
Impact: CBET if any

Very high T, low density plasma, ion acoustic waves determine CBET. Actually modeled mostly as collisionless plasma. Per an Ed Williams estimate in 2012, ion MFP 14µm. Kinetic effects could affect nonlinear damping?

Gas filled hohlraum:
Material: He
Density: ~ $n_c/20$
Temperature: 4-5 keV
Impact: CBET

2. LPI as the beam crosses the hohlraum interior

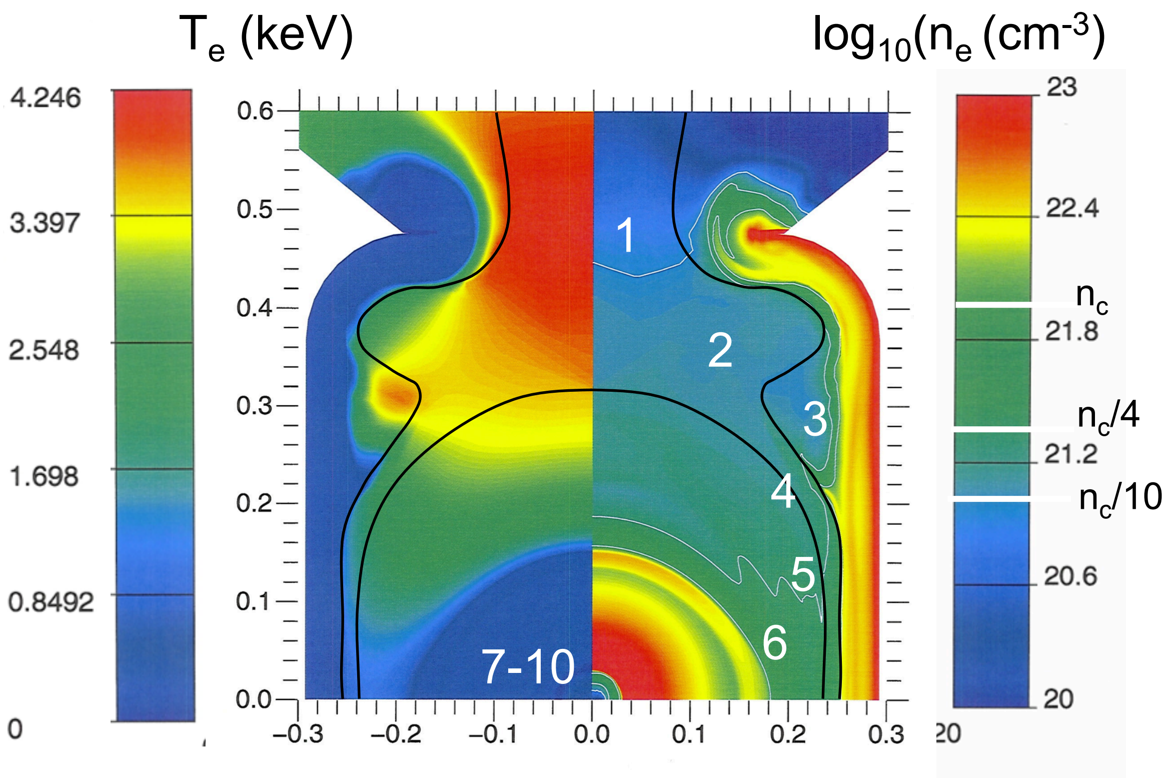


NVH:
Material: Some He, more Au
Density: $n_c/25$
Temperature: 5-6 keV
Impact: SBS, SRS, absorption of SRS, other LPI if any

High T, low density plasma, lots of collisions. In some cases this is certainly a kinetic-effects regime. Probably affects estimates of SRS, SBS, etc.

Gas filled hohlraum:
Material: He and Au
Density: ~ $n_c/10$
Temperature: 3-4 keV
Impact: SBS, SRS, absorption of SRS, other LPI

3. Transport of absorbed energy into the wall

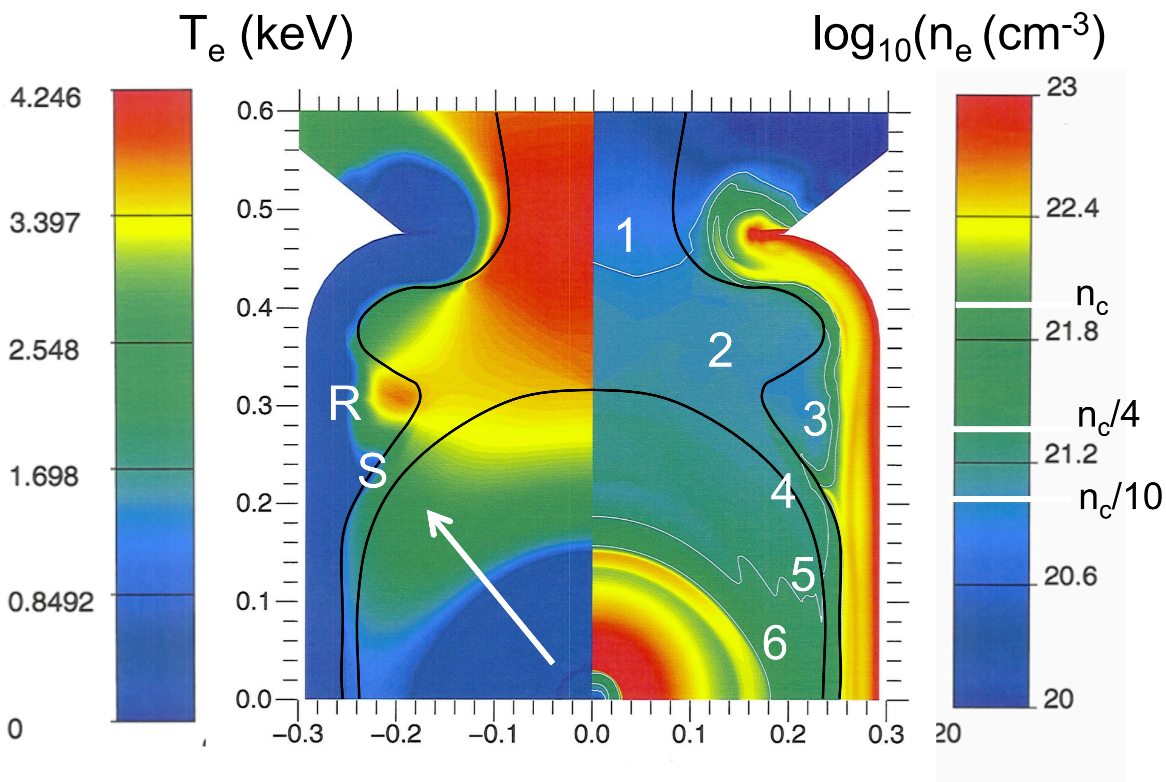


Very high transport in steep gradients with lots of collisions. I bet some talks this week will involve this.

Gas filled hohlraum:
Material: Au
Density: ~ $n_c/10$ & up
Temperature: 1-5 keV
Impact: Our ad-hoc flux multipliers, LPI estimates

NVH:
Material: Au
Density: ~ $n_c/10$ & up (lower than gas-filled)
Temperature: 1-5 keV (higher than gas-filled)
Impact: Our ad-hoc flux multipliers, LPI if any

4. The contour of the hohlraum wall

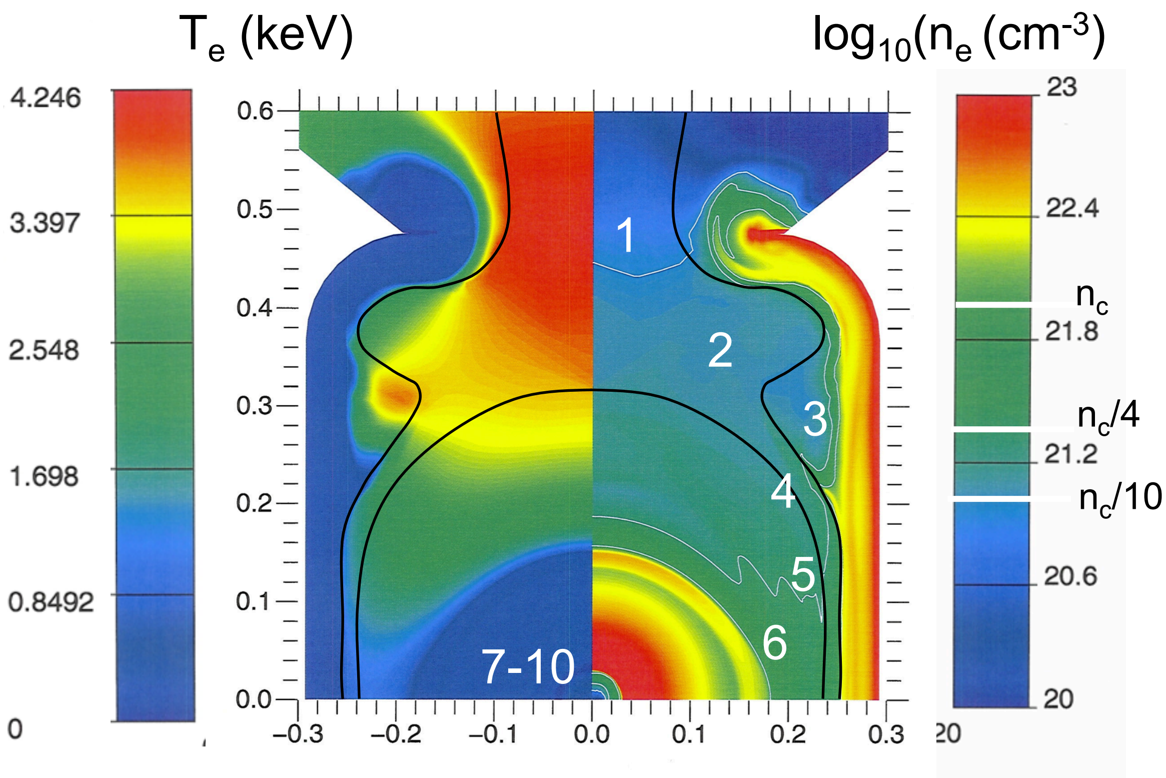


The collisions and hydro affect the contour of the wall, could affect shadowing, transport to the capsule. Our simulations never really "fit" SXI data.

Gas filled hohlraum:
Material: Au and possibly He
Density: ~ $n_c/10$ & up
Temperature: 1-5 keV
Impact: Our ad-hoc flux multipliers

NVH:
Material: Au, which is more contoured
Density: ~ $n_c/10$
Temperature: 1-5 keV
Impact: Our ad-hoc flux multipliers

5. Inner cone absorption/deposition/transport/efficacy

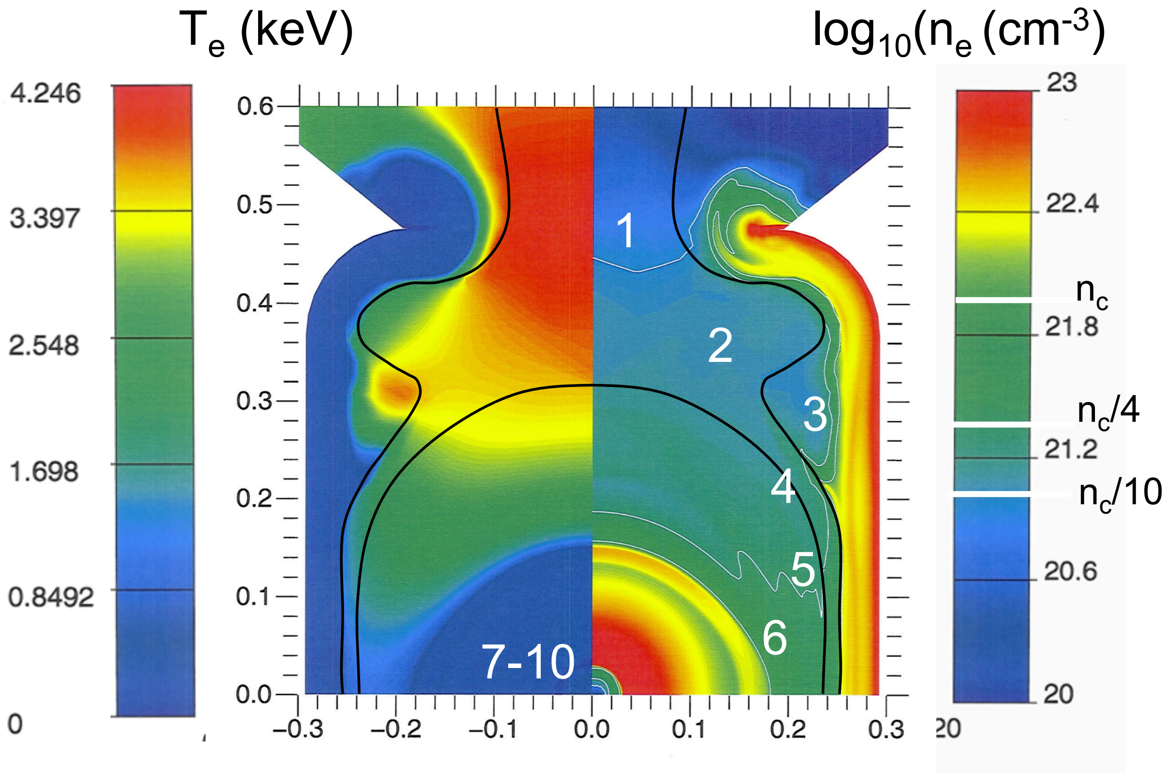


Lots of collisions, compression, fluid assumption very questionable. We know inner cone efficacy is often simulated wrong (Laura BH Xω model for NVH). Even in this nominal simulation the inner cone "disappears."

NVH:
Material: He, CH, and Au
Density: ~ $n_c/10$ - $n_c/4$ (maybe 0.5x gas-filled)
Temperature: 2-3 keV (somewhat higher)
Impact: Our ad-hoc flux multipliers, symmetry

Gas filled hohlraum:
Material: He, CH, and Au
Density: ~ $n_c/10$ - $n_c/4$
Temperature: 2-3 keV
Impact: Our ad-hoc flux multipliers, symmetry

6. Ablator-hohlraum collision

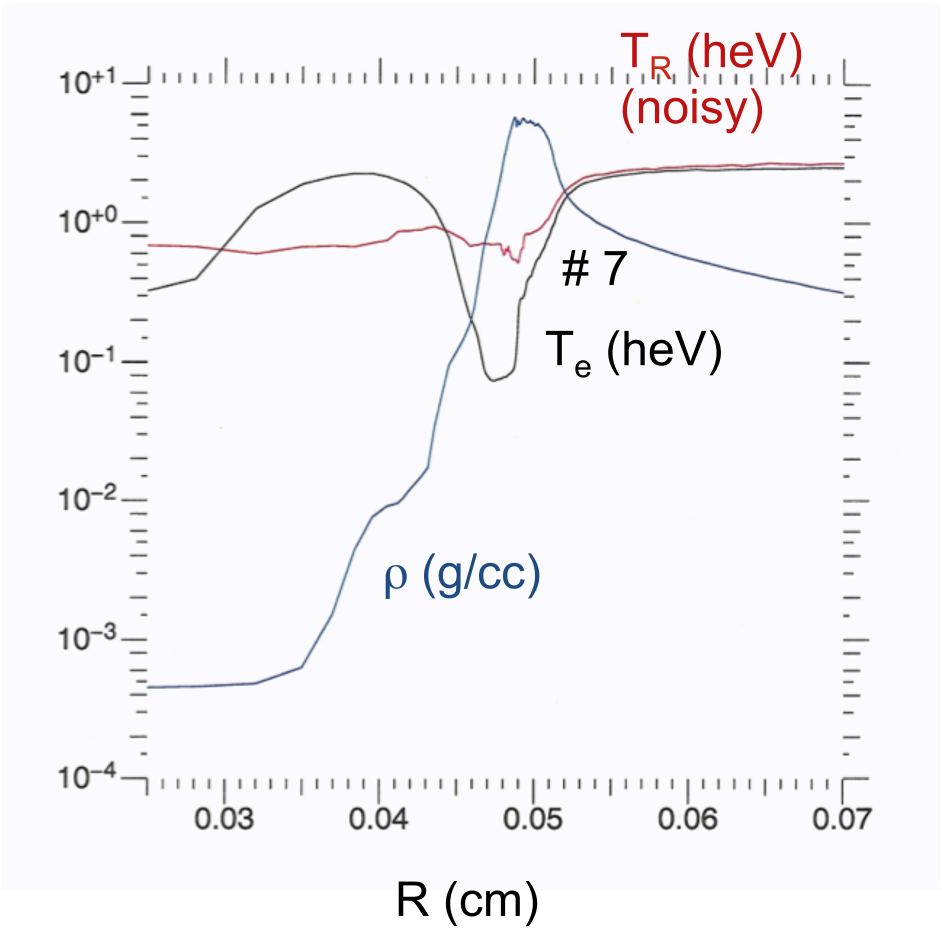


This ring of high density usually appears in simulations, may not be fluid collision. Innocuous in itself, but could affect contour of wall (#4) and inner cone deposition (#5)

NVH:
Material: CH by this time, earlier He/CH
Density: ~ $n_c/4$?
Temperature: 1-3 keV ?
Impact: Our ad-hoc flux multipliers, symmetry

Gas filled hohlraum:
Material: CH by this time, earlier He/CH
Density: ~ $n_c/4$?
Temperature: 1-3 keV ?
Impact: Our ad-hoc flux multipliers, symmetry

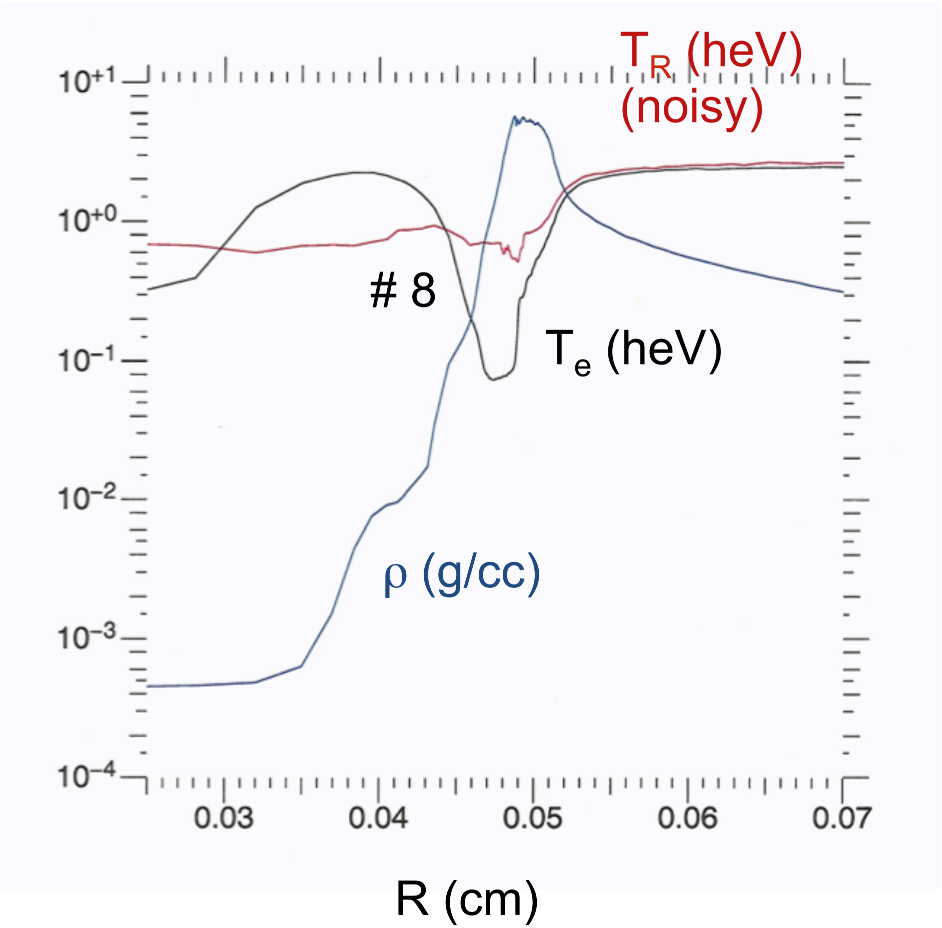
7. Ablator dynamics



Species separation, entropy generation

Material: CH (or Be, or HDC)
Density: ~ 1-10 g/cc
Temperature: 10-300 eV
Impact: Ablation pressure and acceleration, ablator entropy and ultimate confinement, RT instability

8. Fuel dynamics during acceleration

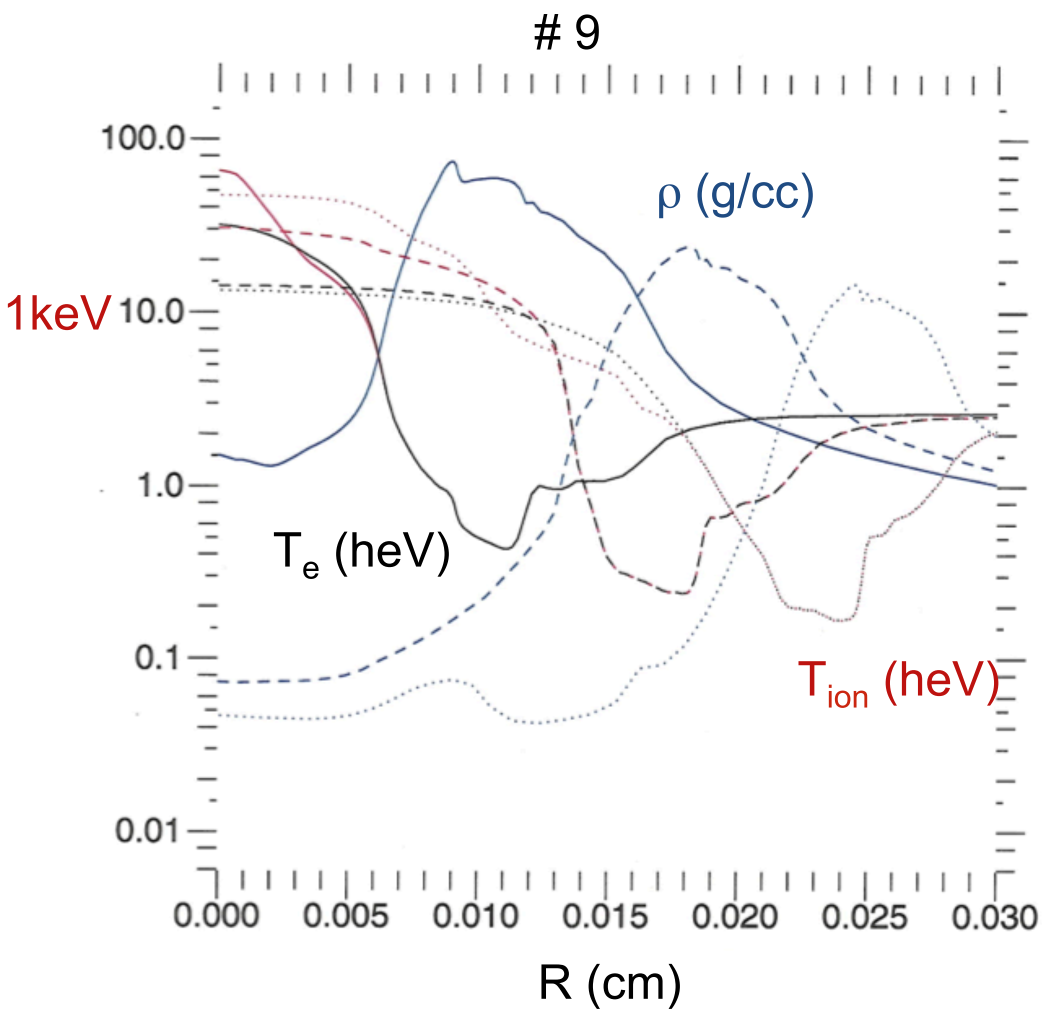


Species separation, entropy generation

Material: DT
Density: ~ 3e-4-10 g/cc
Temperature: 10-300 eV
Impact: Fuel composition, entropy and ultimate confinement, RT instability

9. Fuel dynamics during deceleration

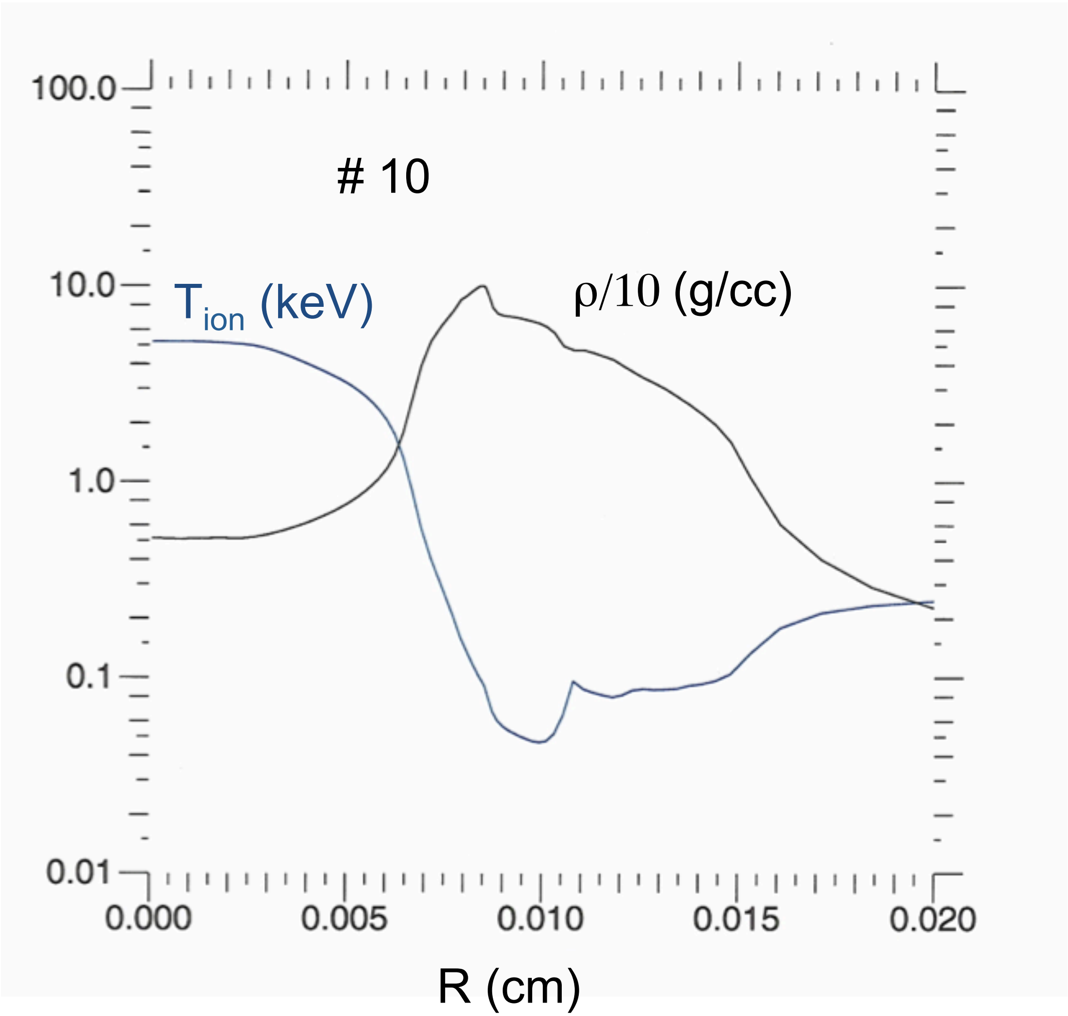
200 ps between snapshots



Species separation, entropy generation

Material: DT
Density: ~ 3e-4-10 g/cc
Temperature: 50-3000 eV
Impact: Fuel composition, entropy and ultimate compression

10. Possible effects on burn per se



Species temperature separation, Knudsen effects

Material: DT
Density: ~ 20-200 g/cc
Temperature: 1-3 keV
Impact: Amount of burn, understanding of diagnostics like "T_{ion}", DSR, other features of neutron spectrum, "T_e"

Summary/conclusion: There is a wide variety of possible effects. How important they might be is the topic of the week

- Kinetic effects are conceivable in many areas
- There are a couple of areas where they almost certainly matter:
  - Wall/gas expansion/collision in NVH
  - Details of hohlraum interior, wall profile, even in gas-filled hohlraums. Could affect SXI images, LPI, ad hoc flux multipliers
- There are a couple of areas where they probably occur but might not matter:
  - Some species separation in the center upon shock convergence
  - Maybe details of hohlraum interior in gas-filled hohlraums don't matter, and ad hoc flux-multipliers result from something else
- In most of the other areas where they might occur, we don't yet have a case that they do. We'll see after this week!

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